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CENTER FOR COMPUTER BASED BEHAVIORAL
STUDIES (CCBS)

Gerald H. Shure, et al

California University

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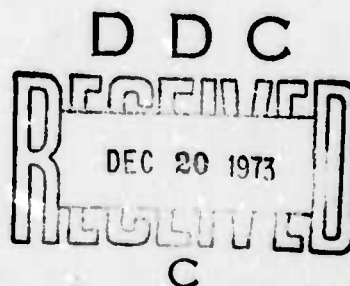
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July 1973



CENTER FOR COMPUTER BASED BEHAVIORAL STUDIES (CCBS)

Regents of the University of CA

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centers, offering them new and powerful research, policy planning, and educational tools. A number of these tools for studying and analyzing the behavior of individuals, groups, and social-political units are specifically capable of narrowing the enormous gap that continues to exist between the policy analyst and the behavioral scientist. Essential to the development of these broad methodological and technological areas is an ongoing program of substantive research in bargaining and conflict resolution behavior relevant to political crisis management. As the three areas of development (laboratory gaming and simulation research, inductive data analysis, and data resources management) share a systematic base of operation, the potentials for mutual support among them will be substantially enhanced. Central to all of these activities are plans based on a number of highly integrated software systems, hardware configurations, and laboratory design and equipment requirements, stemming from ARPA-supported research and development projects conducted over the past eight years.

This document describes project developments covering the first four years placing particular emphasis on progress covering the last six month period and on for project developments for the balance of the contract period. As an aid to the reader who may not have past documentation close at hand, the document as a whole, and many of the internal sections, are prefaced by an overview statement which reflects the general background and rationale developed in the original proposal.

CENTER FOR COMPUTER BASED BEHAVIORAL STUDIES (CCBS)

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Robert J. Meeker
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PUBLICATION REVIEW

This technical report has been reviewed and is approved.

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RADC Project Engineer

Howard Davis
HOWARD DAVIS
TECHNICAL DIRECTOR
INTEL & RECON DIVISION

ABSTRACT

The Center for Computer-Based Behavioral Studies (CCBS) on the UCLA Campus is designed and is being developed to overcome a number of the methodological limitations blocking significant research advances in, and behavioral sciences' contributions to, the study of national policies and problems. The Center is designed around a time shared computer system that will make its informational and technological resources available to behavioral scientists and policy analysts located at widely dispersed university and government research centers, offering them new and powerful research, policy planning, and educational tools. A number of these tools for studying and analyzing the behavior of individuals, groups, and social-political units are specifically capable of narrowing the enormous gap that continues to exist between the policy analyst and the behavioral scientist. Essential to the development of these broad methodological and technological areas is an ongoing program of substantive research in bargaining and conflict resolution behavior relevant to political crisis management. As the three areas of development (laboratory gaming and simulation research, inductive data analysis, and data resources management) share a systematic base of operation, the potentials for mutual support among them will be substantially enhanced. Central to all of these activities are plans based on a number of highly integrated software systems, hardware configurations, and laboratory design and equipment requirements, stemming from ARPA-supported research and development projects conducted over the past eight years.

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PROGRESS ON PROJECT: 1 JULY 1969 THROUGH 30 JUNE 1973

Background and Summary

Progress during the first year of the project was severely curtailed by protracted contractual negotiations; a definitive contract was not implemented and finalized until the last week of June 1970. In sum, the project operated during the entire period without the enablement of a finalized contract and without authorization to acquire the central computing system and its major components of hardware and software support. In the absence of enabling conditions--without definite selection of the central processing system and without contractual authority to purchase major equipment, to subcontract for software development, or to develop project staff--the proposed schedule of development for the first year was critically compromised.

In contrast, the project progressed at an accelerated rate in the next three years; as a result, we have been able to recoup a significant portion of the schedule slippage due to first-year delays. Phase I of the computing system is complete, both with respect to hardware configuration and operating system software. Phase II hardware and software design has been completed and both hardware and software are being implemented. Two higher-order programming languages--JOVIAL and META--have been developed; both META and JOVIAL are now being used for applications programming. Interactive debuggers are available for both these languages. We have developed a programming system that provides rapid and easy laboratory implementation of experimental research designs. In data management and analysis, we have implemented PREP, a common interactive data base interface to data analysis programs and packages, TRACE III, a system that provides implicit programming capabilities for data analysis, handling complex data structures, both hierarchical as well as rectangular, and a fully interactive and augmented version of IDEA, a program that provides computer

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assistance in the task of inductive data analysis. The construction of permanent laboratory facilities is complete. CCBS is being interfaced with the ARPA network as a means of offering our capabilities to a wider community of users.

Computer Laboratory Developments

The principal goal of the project is to broaden and expand the capabilities of behavioral research, particularly in areas of potential policy relevance. The principal means of accomplishing this goal is to develop new behavioral research methodologies through the use of on-line, data acquisition tools, particularly for computer-administered experiments and simulations and for interactive forms of data and text analysis. The goals of the project, then, are predicated on developments critically linked to a large-scale timesharing computing system.

Computer Hardware

The hardware configuration of the CCBS central system computer is designed to support high-speed interaction with many concurrent users who, in the three primary applications of the system, may be any mix of experimental subjects, data analysts, and development programmers. The different applications (and associated different types of users, require different interactive service needs, which, in sum, present a need for greater than normal communications processing. The basic hardware configuration is especially designed to meet these requirements.

Beyond the basic configuration, the major extension of computer hardware is to meet extended data management requirements, especially as these relate to the management of data bases of archive proportions. (This aspect of the project is identified in the original proposal as Phase II development.) There are two major facets in extended data management capabilities: first, a need to provide greater data storage capacity in the system, and,

second, a need to provide improved means of accessing data when it resides outside the normal bounds of direct addressability (i.e. core memory). The first of these requirements is being met with the acquisition of additional standard disc storage. There is, by contrast, no standard hardware available for meeting the second requirement; we have therefore undertaken the development of hardware and associated software necessary to support virtual memory programming. A further extension is required to meet increased use of the central processor as the number of concurrent users increases; this will be achieved through an increase in the amount of swapping storage.

A summary of the computer system hardware is given below:

CCBS computer system hardware, basic configuration:

Processor: DEC PDP-10/PDP-15 dual processor--both processors interface to PDP-10 core (262,144 words of 36-bit, 1.5 μ sec. memory) with 12,288 words of 18-bit, 0.8 μ sec. memory on the PDP-15; interprocessor memory interface, DA15-C, developed by DEC (detailed description in Appendix B, Technical Report 12/31/70); and high-speed communications interface, developed by DEC (detailed description in Appendix C, Technical Report 12/31/70). Virtual memory hardware is under development that will permit most of the instructions on the PDP-10 to reference directly over 8 billion words of storage.

Auxiliary storage devices on the PDP-10:

- Fixed-head (Drum and Disc): 2 swapping drums. DEC RM10B (storage capacity of 345,600 words each, mean access time of 8.3 msec., and transfer rate of 4.1 μ sec. per word). An order has been placed for a swapping disc of 1.2 million words with a mean access time of 12 msec. and transfer rate of 3 μ sec. per word.
- Moveable-head (Disc): 5 disc-pack drives. Four DEC RP02s (storage capacity of 5.2 million words per pack, mean access time of 62.5 msec., and transfer rate of 15 μ sec. per word) and one DEC RP03 drive with twice the storage of an RP02 but otherwise equivalent performance). An additional RP03 disc-pack drive is planned for acquisition.

- DECTape: 6 drives, DEC TU56 (storage capacity of 367 thousand characters per tape, mean access time of 10 seconds, and transfer rate of 15,000 characters per second).
- Tape: 3 drives--one 7-track industry standard, DEC TU20B (45 in./sec., density to 800 bpi.); one 9-track USASI standard, DEC TU20A (45 in./sec., density at 800 bpi.); and one 9-track TU10 (performance is equivalent to TU20A).
- Card: card punch, DEC CP10A (200 cards per minute); card reader DEC CR10A (1,000 cards per minute).

Auxiliary storage devices on the PDP-15:

- Disc: 1 fixed head track. DEC RS09 (storage capacity of 262,144 18-bit words, mean access time of 16.7 μ sec., and transfer rate of 16 μ sec. per word). Additional disc storage will be acquired during the last half of the year.

Printer Plotter:

- Gould, model 55-5032-100--text and graphics; 96 printable characters; print rate: up to 1,000 lines per minute for a 132-character line access on 11-inch page, processor-limited; plot rate: up to 8 inches per second for 11-inch wide plots, processor-limited.

Communication terminals:

- High-speed graphics terminals: 24, Computek Model 400/15; storage tube; text/graphics display, keyboard and light-pen input; 96 printable characters; transmission rate: 7200/300 baud.
- High-speed text terminals: 24, Ann Arbor controller, Model 208A; locally refreshed CRT; text display (24 lines of 80 characters); keyboard; 64 printable characters; transmission rate: 2400 baud.
- Hard copy terminals: 5, Texas Instrument Model 720; 95 printable characters; transmission rate: 300/150/110 baud.

The system described above is essentially complete--except for the items indicated as being on order or under development, all components have been acquired and are operational.

One major modification to the hardware system is underway in the area of data management:

Extended data management--the hardware necessary to support virtual memory programming is being developed by CCBS; the design concept has been implemented by software simulation (the SMART system described below); a design study of the virtual memory hardware has been completed, and detailed documentation and logic design are complete; hardware fabrication has started.

Accomplishments during the current reporting period relating to system modifications:

- Start of fabrication of virtual memory hardware.

Computer Software

Software developments are oriented toward on-line data acquisition techniques (computer-administered experiments and simulation) and interactive forms of data analysis. There are two major lines of development: General support and applications support--general support programming provides the software environment for applications support programming which, in turn, provides the software-implemented methodology for the end-users in the system. Within the general support effort there are two areas of concentration: Operating system and higher-order languages. Within the applications support effort there are also two areas of concentration: Laboratory research and data analysis.

Operating System Improvements

CCBS requirements for a timesharing system are somewhat atypical--in particular CCBS users are typically not all one class, are not usually programmers, and are often not independently related to a given object program. In some respect each of the differences is at variance with assumptions that are built into standard time-sharing system supplied with the DEC PDP-10 computer. It has been necessary, then, to modify the operating system to CCBS needs. While none of these modifications are in the class of major technical innovations, and while none by itself constitutes a major revision, they are, on the other hand, nontrivial changes and represent, in sum, a significant programming effort. The major modifications are listed and briefly described below:

Interrupt-level communications support--because of the high data rates used by CCBS local terminals, the organization of the interrupt-level communications handlers has been revised to permit most of the interrupt-level processing to be performed by the PDP-15 rather than by the PDP-10. The benefits of this reorganization will become apparent only with the completion of a new PDP-15 operating system that is currently under development, partly in support of this contract and partly in support of the ARPA Network contract, F30602-72-C-0299. One of the consequences of the new PDP-15 system will be the capability to offer greatly expanded support for display terminals without burdening the main processor.

Terminal interactions--all terminal interactions in the delivered DEC system assume continuous-scroll output; to match the display characteristics of the Computek terminals, terminal output had to be "paged." Additional changes were required to permit several terminals to be controlled by one program and to provide software control over the way the system supports the terminals.

Disc and tape access--access to peripheral storage in the delivered DEC system is assumed to be a user responsibility with only minimal provision for system protection and assistance. To accommodate naive users, peripheral storage access procedures have been modified.

Device assignment--in the delivered DEC system, the assignment of access devices for private data storage are assumed to be a user responsibility; again, to accommodate naive users the operating system has been modified to provide new procedures, better protection, and greater assistance in device assignment. These improvements are generally applicable to all PDP-10 systems; documentation is contained in TM-13.

(In addition to modifications of the operating system monitor, the manufacturer-supplied general utility programs also required extensive modification and augmentation.)

Disc file backup--as the disc storage system nears saturation, the performance of the overall system degrades (because of the need to fragment files) and there is a sharp increase in the likelihood that jobs that create or expand files will not run successfully. To overcome these problems, a disc file backup utility has been developed that automatically removes long-unused files from disc onto magnetic tape whenever disc availability drops too low; files with the oldest access dates are removed first. A complementary utility has been developed to permit users to recover files from the backup. A corresponding modification was made to the disc directory utility to prevent modification of a file's access date in a manner that would subvert the purpose of the disc file backup utility.

Loader modification--to permit a user to call on the JOVIAL Debugger by means of similar protocols to those used for conventional debugging, and to permit both debuggers to be used on the same job, the DEC-supplied loader had to be modified.

Terminal support--the Computek terminals, which serve as the primary interactive devices for the system, are considerably more versatile than the normal devices upon which DEC utility programs are predicated; to fully utilize the versatility of the Computek terminals, the DEC utility programs had to be revised. Additional changes were required to take advantage of the locally refreshed displays of the Ann Arbor terminals.

Text Editor--two editors were delivered with the hardware; neither was considered adequate for the broad class of users in CCBS; a new text editor has been implemented; this editor is generally applicable for all PDP-10 systems; documentation is contained in TM-10, TXTED: A Simple Content Editor.

Beyond these modifications, a significant revision of the operating system is under way. This revision is required for the development of an extended data management capability (i.e. the software side of developing virtual memory capability). As mentioned previously, the virtual memory design has already been simulated in a software version. The emulation of virtual memory hardware is part of the SMART system, but, in addition to emulating the virtual memory hardware, SMART also performs elaborate core management services; it is these core management services that constitute the operating system revisions. (The core management concepts of the SMART system are described in P-4, SMART: A Multiple-High-Segment Executive System.) They will be incorporated into the timesharing monitor after the virtual memory hardware is acquired. The affected components are the assembler, loader, schedules, file service, and core management function.

Under another contract (F30602-72-0299) the operating system software is being modified and extended to provide an interface to the ARPANET. These software activities, concentrated primarily in the PDP-15, involve a new PDP-15 monitor and the ARPANET NCP and TELNET functions. The new monitor supports interrupt-driven multiprocessing, so that ARPANET functions can be timeshared with communications processes and other laboratory support functions

operating in the PDP-15. This monitor is now fully operational. The Network Control Program (NCP) supports interaction between the PDP-15 and the IMP (Interface Message Processor) to receive and send Network messages: the TELNET function provides the interface between NCP and either the local terminal or the PDP-10. Both of these functions are expected to be checked out by September 1973.

Higher-order Language Developments

The CCBS research program imposes requirements on the type of higher-order programming languages that are needed to support the development of application system. In particular, the computer-administered experimentation implies a need for programming forms that facilitate real-time process control, and interactive data analysis implies a need for programming forms that facilitate general data manipulation and mangement. When the PDP-10 computer was acquired, the higher-order languages available on the machine were evaluated for CCBS applications and were judged to be inadequate; a higher-order language development was required. A modified JOVIAL and META were selected for implementation--JOVIAL because it had a history of performance in both command-and-control systems and data management, and META because it had proven utility both as an interface between JOVIAL and intermediate language forms (of the type contemplated in CCBS applications), and as a powerful, character-string manipulator (to aid in restructuring data bases).

Both JOVIAL and META are now operational in the CCBS system. Since both are programs of general utility for all PDP-10 systems, general releases are planned when the compilers have been shaken down and thoroughly documented. Experience with using both of these compilers in an interactive environment has demonstrated the need for improved on-line debugging aids that permit the user to communicate in the notation of the higher-order language source program. Such interactive debuggers have been defined both for JOVIAL and for META. A partial implementation of a META debugger has been developed and is now in use and an interactive JOVIAL-language debugger has been incorporated into the JOVIAL system. These debuggers have led to a great reduction in time required to check out META and JOVIAL programs.

During the past winter quarter, an operational version of UCI-LISP has been implemented in the CCBS system. Developed by the Department of Information and Computer Science at the University of California at Irvine, UCI-LISP is a compatible extension of the earlier Stanford LISP 1.6 for the DEC PDP-10. The extensions, which are very considerable in their scope and impact, make UCI-LISP a powerful and convenient interactive programming environment for research, teaching, and systems development in artificial intelligence and advanced list processing applications. Most of UCI-LISP's extensions to Stanford LISP were suggested by the novel features of BBN-LISP (a language available only on TENEX systems), including: uniquely sophisticated breakpoint, tracing, and function editing capabilities; interpreter context manipulating functions; more powerful and convenient I/O facilities; a variety of useful new functions and predicates; greatly improved error protection facilities; a reentrant sharable high segment, which accommodates compiled code. In addition, UCI-LISP offers a more efficient compiler than BBN-LISP, and requires an order of magnitude less core storage to operate. CCBS is the first institution outside of Irvine to implement the UCI-LISP package.

Laboratory Software

On-line, computer-administered experimentation is, for many behavioral researchers, a relatively unfamiliar method of investigation. They have had little or no experience with the process control programming even if they have used computers extensively for data reduction and analysis. They would, then, have difficulty using the laboratory without a considerable degree of assistance; the problem is analogous to using a computer without the assistance of high-order languages; the analogous need is to provide a "research-design compiler." CCBS has developed this sort of software support in the form of a system of programs called LIS: Laboratory Implementation System. A more extended description of the general rationale of LIS is contained in P-1, LIS: An Implementation System for Computer-based Experiments. The total Laboratory Implementation System is composed of four programs described below:

LIS--The central and major program in the system. The program handles all routing of information, evaluation of responses, presentation of displays, recording of data, and logic contingencies necessary for implementation of experiments. The program is operational; shake-down experience has substantiated the design concepts--for a broad set of applications we can produce a meaningful implementation in a matter of days. In the design and implementation of LIS we have adopted a strategy of incremental development; improvements to LIS are made in response to need; when a user has a need beyond the current general capabilities of the system, the need is satisfied, directly, with the development of a special processor; if the special processing capability is judged to be general in character it is then incorporated into the system. Experience thus far has revealed the need for more versatile display control than was originally implemented; general controls are being implemented.

LSPEC--Laboratory Specifications Program. This program presents an interactive questionnaire to the user; responses to the questionnaire are the basis for generating formal specifications for a "first-cut" version of an experiment. The response-to-specifications is automated. The resulting specifications are sufficient to check out the logic of the experiment; if modifications are required, the system offers an easy transfer to the LISED program (to make the necessary changes) and an easy transfer from LISED to LIS (to reflect the changes made). Iterations on this process permit the user to successively approximate his final research design. Elaboration of the display content is handled through DGP with comparably easy transfers between LIS and DGP.

DGP--Display Generation Program. This program is used for preparing displays composed of straight-line graphics and alphanumeric information for use in experiments or for educational purposes. The procedures for preparing displays are conversational; the user language has been designed for a nonprogrammer, with operating instructions incorporated directly into the program. This program is operational. Further developments in the area of display generation are being concentrated on improved graphics capability, so the system will be better able to handle situational displays.

LISED--Table Editing Program. LIS operates interpretively on a set of tables whose entries contain values defining a given experiment. The initial setting of these values into the tables is the most exacting and time-consuming procedure in the process of implementing an experiment; for any given experiment, this is a one-time task almost exclusively clerical in character. As a practical expedient we have committed this task to a stand-alone program that can be used by a clerk-typist; this frees professional personnel from the most time-consuming aspect of the implementation process. This program is operational.

Accomplishments during the reporting period which relate to laboratory support software development:

- Extended display capability in the LIS system.
- Modifications in implementation functions to achieve compatibility with nongraphic communication devices.

Management and Analysis of Data and Text

CCBS efforts in data management and analysis are focused on forms of interactive data analysis that will allow a substantive expert (the researcher, the policy-maker, the policy-analyst, the decision-maker, etc.) to exercise his judgment in the course of the analytic process. The principal efforts in this direction are the TRACE III and IDEA II developments. In addition to the data analysis systems that we are developing we are also concerned with interface to statistical programs that have been developed elsewhere and with the interface between these systems and our own. To facilitate this interface problem we have developed PREP I, a data base preparation system that interfaces to all analysis programs on our system.

In the area of text analysis, we are modifying an interactive recursive transition-network sentence analyzer for thematic analysis. The latter is designed to augment standard content analysis of text with thematic or sentence-analysis components. The resulting Theme Encoding System (TES) is intended to provide a considerably more sensitive and less ambiguous analysis of verbal text materials.

TRACE III--This is a highly general system of programs that produce the equivalent of an implicit programming system. Implicit programming is tantamount to "natural-interaction"--the user does not need to be explicitly concerned with data management; all data management is accomplished without direct specification. Functionally, this transforms the user into a data analyst technician without having to know or exercise data analysis computing techniques. The support that enables this sort of functional transformation is extensive and complex. TRACE is composed of five major

components: a compiler that interacts with the user; a data-base management component that builds the primary data structures; a retrieval component that restructures and associates subsets of data for manipulation; a manipulative component that acts on the resultant data structure to produce the desired results; and an update component that reincorporates derived data into the primary data structures. (A description of the TRACE system is contained in P-2, TRACE: An Implicit Programming System for Inductive Data Analysis.)

The CCBS virtual memory developments afford a direct extension of the TRACE concepts; virtual memory extends the implicit programming capabilities to large data systems that exceed core memory limitations.

An initial implementation of TRACE III is available on the CCBS system; it can be used independently or can be accessed through PREP. TRACE III is being revised and made more reliable as shakedown experience is gained in its use.

IDEA--The IDEA program offers an inductive aid to a researcher for discovering and summarizing potentially interesting data models in the form of restricted tree structures for a multivariate data base. It permits the investigator to collaborate with an open-ended library of programmed heuristics in the process of uncovering and representing the structure of his data.

The interactive aspect of IDEA is essential since the number of potential decision trees for any interesting set of data is too large to permit exhaustive search for the best partitions, and the character of the data may be inconsistent with exhaustive search even if it were computationally possible. The program is thus designed to employ heuristics and to permit the investigator to monitor the process and to intercede when slavish application would produce artifactual results.

A fully interactive version of IDEA II is available on the CCBS system. It is continually being modified with user experience and additional capabilities. A revised version of "A Users Guide to IDEA in the CCBS System" has been completed (CCBS-TM-24).

PREP I--Before a statistical analysis program may be applied to a data base, the data must be prepared. This usually involves a number of activities that may include ordering of the data, checking it for accuracy, and correcting and modifying values; and revision of distribution parameters and recording or transgeneration of values if desired or necessary.

PREP I is a system of computer programs providing a common data base interface to data analysis programs and packages. The PREP system provides a high degree of user support that minimizes user knowledge about programming conventions and operating system functions. The user need enter and edit his data only one time to use any of the data analysis programs that interface with the PREP system. The necessary, but usually troublesome and error-laden, process of data preparation (entry, verification, and prestatistical manipulation) is concentrated and standardized for all data-analysis programs supported by the PREP system. The distinguishing feature of PREP is that it concentrates analysis preparation functions and yet remains an open-ended system in terms of the analysis programs that it supports. This contrasts on the one hand, with "integrated" systems like SPSS and DATATEXT which also provide data preparation capability but are essentially limited to those analysis programs included in the "integration package"--i.e. it is very difficult to add new statistical programs to these packages. Furthermore, PREP provides considerably more (user-oriented and interactive) support in analysis preparation than either of these "integrated" packages, and it does so in a manner that makes it possible to apply these capabilities to an easily expandable set of data analysis and statistical programs. In this respect PREP is best viewed as an "interfacing system" rather than as an integrated package. PREP contrasts, on the other hand, with a large set of "stand alone" analysis programs in statistical library packages (e.g. BMD) in which each program provides its own unique set of data preprocessing and preparation functions required for its own use. As a consequence, these capabilities are typically limited in scope, and not standardized from one program to the next. From the standpoint of the user, this means (1) he must learn to use each program on its own terms, and (2) the results of the data preparation for one program cannot be transferred directly to another. In summary, PREP, (1) concentrates this learning process (one set of procedures for all applications), (2) reduces it in the sense of giving the user considerably greater assistance in the analysis preparation tasks, and (3) makes the results available to all interfacing analysis programs.

The PREP system incorporates four major processing functions--input, verification check, editing, and interface. The input function accepts data from the conventional sorts of machine-readable storage mediums, producing a transposed data structure for the greatest efficiency of selected data retrieval. The verification check offers a variety of "quicklook" data summaries as a means of verifying the accuracy of the original and stored data. The editing function provides a number of procedures for error correction, data recoding, and data transformation. The interface function is, of course,

different for each of the programs being interfaced to the PREP system (and each must be separately produced), but since they all relate to a standard data structure, there is, even among the variety of interface requirements, enough commonality to make it a clear and practical programming task to bring most standard existing or new data analysis programs into the system.

The PREP system, implemented in standard FORTRAN IV, has a high degree of transferability to other computing installations; particularly important in this regard is the fact that PREP requires no special operating system support, and that it is not preemptive (i.e. it permits the analysis programs that it supports to be used in the conventional manner, thus making the same analysis programs accessible to expert users and naive users as well). All SPSS statistical programs and IDEA currently interface with PREP.

Archive Management--Archive management has been an essential part of the CCBS concept of development, even from its inception. Actual development was necessarily deferred until the enabling software tools had been implemented, and complete development of the capability will not be fully realized until the Phase II system--virtual memory hardware and software--has been implemented. As a step toward that development, archive data management has been incorporated into the PREP system, affording interface, on the input side, with archive data files, and interface, on the analysis side, with all programs supported by the PREP system. The software for PREP access to archive data files is now fully operational and part of the CCBS User Package.

A number of archive files have been acquired and incorporated into the CCBS system. These files are stored as public data, available through the CCBS User Package; through PREP, the user selects from the public files to create his own data base which can be manipulated, with PREP functions, to his own purposes; the private, working files can be deleted when the user no longer has need for them. In the public-to-private selection process, the user can select subsets of variables and/or subsets of observation (by a number of sampling options). The public files are protected against user modification--aside from the selection function, they are unavailable to user manipulation.

Early experience with the archive files has revealed a need for a general restructuring function. Users of archives, generally, have seen the need for such capabilities, but without the availability of general data management software (at the user level), they have either restructured the data by hand or have had single

application programs written for this purpose. By contrast, in the CCBS system, TRACE offers general data management at the user level; thus, with the establishment of a PREP-TRACE interface, a general restructuring function would be available to archive users. This interface has been designed and is currently being implemented as an additional step toward a complete archive data handling capability.

The archives incorporated into the CCBS User Package to date include the following:

- World Handbook Daily Event Data--This contains reports on seventeen political event types during the twenty-year period 1948-1967. One hundred thirty-six nations are represented. There are 57,268 records: one for each event type for each nation.
- World Handbook Annual Event Data--This contains data on eighteen political events aggregated by year; events recorded for the twenty-year period 1948-1967. Event types included are riots, deaths from political violence, political assassinations, armed attacks, elections, protest demonstrations, regime support demonstrations, political strikes, renewals of power, unsuccessful executive transfers, regular executive transfers, executions, acts of negative sanctions, acts of relaxation of political restrictions, and external interventions.
- World Handbook Intervention Data--This contains data for interventions recorded at daily intervals during the twenty-year period 1948-1967. The daily report is the unit of analysis. There are 1073 records, one for each day in which an intervention occurred in a country. The number of records per country varies. Those countries that were not involved in any type of intervention are excluded. Data are recorded for 89 of the 136 nations in the sample and for two international organizations. Some of the variables included are the number of interveners, type of group involved, air and naval incursions, and length of intervener's presence in the country.
- World Handbook National Aggregate Data--This contains data on 136 polities on some 300 variables. Included are indicators of population size and growth, communications, education, culture, and economic and political variables for the four base years: 1950, 1955, 1960, 1965. Data for 1965 are about 90% complete, but the proportion of missing data is much higher for the three earlier years.
- Dyadic Disputes: National Attributes of Participants--This contains data on disputes recorded at the Permanent Court of International Justice (PCIJ), International Court of Justice (ICJ), League of Nations, and the United Nations in the international bargaining process.

Data are included for all disputes (1) which occurred between 1920 and 1968; (2) which were dyadic (i.e. in which only two states were involved); and (3) which were considered in at least one of the four institutions. This section includes data for each participant for each case. Variables include age of the state at the time of the dispute, type of political system, stage of economic development, social-cultural region, the country's role in the introduction of the dispute and others.

•Dyadic Disputes: Patterns of International Usage by Participants--Data are included for all disputes (1) which occurred between 1920 and 1968; (2) which were dyadic (i.e. in which only two states were involved); and (3) which were considered in at least one of the four international institutions named above. This section provides information on the usage of each participant. For example, variables include total number of cases in which the country participated, a weighted index of participation and the number of cases jointly submitted.

•Dyadic Disputes: Attributes of Cases--In the dyadic dispute series, this provides information on both the attributes of each case and on the dyadic attributes of the two members of the case. For example, data were collected for the following variables: manner in which the dispute was introduced to the institution, the institution used, type of issue associated with the case, hostilities associated with the case, success of the institution in stopping the hostilities, outcome of the dispute, relative power capability of the disputants, distance between the disputants, economic interdependence of the disputants, and similarity of social-cultural regions.

•WEIS (World Events Interaction Survey) data are described on page 22.

TES--Interactive Automatic Theme Encoding of Messages and Documents for Content Analysis. There exist numerous applications in industry, government, and within the academic community, for systems that can rapidly and reliably process ordinary natural-language text with a minimum of semantic distortion. Applications such as document routing, profiling, indexing, classification, and abstracting all require that a sharply condensed summary of a document's contents be derived and cast in appropriate output form. Other applications, such as the triggering of alarms, also require that the processor "understand" the document in some sense.

An academic paradigm for these tasks is provided by the field of content analysis, especially of the more sophisticated Stanford type. The scholar seeks an unbiased, accurate, and compact reading of the object text. He obtains this by first boiling the text down to its thematic content, informally, the set of bare-bones assertions that

can be identified in the text. He then applies his content-analysis procedures to the set of themes. It has been our contention that this set of themes is an immensely useful document surrogate not only for content analysis but also for the other applications mentioned. Within CCBS, these tools are being employed in the analysis of message sets originating in experimental gaming situations, studies of social interaction, and group simulations, as well as for the analysis of outside documents of interest. Themes have the following advantages over ordinary text for these purposes: (1) they are compact, generally containing only a fraction of the original textual material, and (2) they are highly and simply formatted, so that they can be further processed by relatively simple nonlinguistic programs.

The main tool employed in such studies is the Stanford Inquirer, a more sophisticated version of the earlier General Inquirer. The use of the Stanford Inquirer on a large scale has heretofore involved considerable costs and a great deal of time for the object texts to be precoded manually to isolate the themes of interest in the text. Moreover, manual text encoding has been subject to inconsistency and bias. Our work at CCBS seeks to transfer most of the burden of theme recognition and encoding from people to computers, using the most advanced and comprehensive techniques of computational linguistics. In earlier reports we have described the hardware and software environment of our development effort. Our theme encoder is partially operational now, and will be fully operational in the near future. The following discussion is intended to provide a perspective on this development.

Fundamentally, themes in English are reduced deep sentential structures. That is, actors derive from deep subjects, actions from deep verbs, and targets from deep objects. Of course, at the level of surface structure this relationship is not immediately apparent, and that is the primary justification for our use of sophisticated language analysis programs: to make available for them recognition and encoding the deep structure of input sentences.

Having before it the deep structure of a sentence, the theme-encoding function then faces the task of finding the actor in the subject, the action in the verb structure, and the target in the object. We can gain some insight into the theme encoding process by considering a number of ways in which the thematic elements may be contained in the corresponding linguistic structures.

In English, subjects and objects are noun phrases, distinguished by their positioning relative to the verb--the subject precedes and the object follows (in deep structure). Without loss of generality, we may discuss the actor/subject relationship, remembering that our remarks apply with equal force to the target/object relationship as well.

- (1) In the simplest case, the actor-name is itself the subject, as in "EGYPT ATTACKED LIBYA." Of course there may be modifiers as well, as in "HOSTILE AGGRESSIVE EGYPT ATTACKED..." Further, modifying clauses may be present (and may themselves contain themes): "THE AGGRESSIVE EGYPTIANS WHO HAD CONQUERED LIBYA INVADED SINAI."
- (2) At the first remove from this simplest situation, the actor-name appears as a modifier for the subject. First, it may appear as a modifier at the same level as the grammatical subject: "THE EGYPTIAN ARMY ATTACKED LIBYA."
- (3) Next, it may be contained as the nominal head of a prepositional phrase at this level: "THE ARMORED UNITS FROM EGYPT ATTACKED SINAI." We might pause here to consider two technical questions concerning these situations. First, in what ways will our identification of thematic elements depend upon the particular preposition involved? Clearly, the preposition cannot be ignored; consider "THE TROOPS FROM EGYPT ATTACKED LIBYA" vs. "THE TROOPS OUTSIDE EGYPT ATTACKED LIBYA." Second, what is the thematic status of the head of the grammatical subject (e.g. TROOPS in the given sentences)? With the help of content-analysis experts within CCBS, empirical work on the first question continues, and a satisfactory solution appears to have been found. In the second case, it has been decided to encode such headwords as thematic modifiers of the corresponding actor: ...TROOPS/3 EGYPT/3*...
- (4) Further along, the actor-name may appear two or more layers deep in prepositional phrases modifying the grammatical subject: "ARMIES FROM THE NORTHERN PART OF EGYPT INVADED LIBYA."
- (5) Grammatically more remote still from the simplest case, the actor-name may appear as a modifier within a prepositional phrase, at various levels of depth: "ARMIES FROM THE EASTERN EGYPTIAN PROVINCES ATTACKED LIBYA," "ARMIES FROM THE COASTAL REGIONS OF THE EGYPTIAN TERRITORIES ATTACKED LIBYA," etc.

In these cases, as in those that follow, we are concerned with a grammatical analysis of the situations not for their intrinsic theoretical interest but because we wish at all times to accurately and reliably distinguish thematic roles of the actor-names from nonthematic or secondary-thematic roles. It would, of course, be simpler and cheaper to ignore all of the structural considerations we have discussed, and to mark as thematic actor any actor-name appearing anywhere within the grammatical subject. This sort of approach has been advocated, and even implemented, for some applications. But we should then prepare ourselves to accept gracefully whole classes of wrong encodings that would predictably result. Consider "THE ARMIES FROM THE BORDER AREAS NEAR ELATH INVADED ISRAEL," etc. In short, we want our analysis to be sufficiently fine to enable us to sort out these cases.

- (6) Let us now turn from the actor/subject relationship to a whole class of themes that have so far been implicitly excluded from consideration. In sentences like: "THE SUDDEN ATTACK BY EGYPT ON LIBYA WAS DENOUNCED BY FRANCE" an obvious theme occurs in the opening phrase (THE SUDDEN ATTACK BY EGYPT ON LIBYA...), yet this phrase is not overtly a sentential structure. It may be regarded as a nominalization; it behaves syntactically as a noun, but may be viewed as derived from the deep sentence: "EGYPT SUDDENLY ATTACKED LIBYA." Here, obviously, is another rich source of themes in English. Interestingly, all of the foregoing kinds of actor-recognition problems are reflected within the domain of nominalized sentences. At first glance, this may seem to imply an immediate doubling of our problems. In fact, however, the very same machinery may be used to handle both sets of cases, if it is properly designed. Notice the following nominalizations: "EGYPT'S ATTACK ON LIBYA," "EGYPT'S SUPPORT OF PALESTINE," "EGYPT'S AID TO SYRIA." It is a characteristic property of these structures that the direct-object (or target) of the underlying sentence is marked by a particular preposition (underlined) which is dependent upon the deverbative noun (ATTACK, SUPPORT, AID). Successful processing of these structures requires that we mark deverbative nouns in the lexicon with pointers to their deep verb and their object-marking preposition(s)--a task in progress as of this writing.
- (7) Finally, consider the problem of elided or "gapped" elements, as in "THE ATTACK ON LIBYA WAS CONDEMNED IN THE U. N.," where the deep actor/subject of the deep verb ATTACK is not given. An intelligent theme-encoding system should be able to make statistically useful guesses to fill in such information on the basis of remembered actors, actions, and targets for a reasonable number of preceding sentences or themes. But to make such guessing usefully accurate and reliable will not be an easy task. We will defer deeper discussion of this issue to later reports.

We have sketched seven technical problem areas of theme recognition and encoding, with occasional mention of the implementation difficulties associated with them. This is not an exhaustive account of the theme-encoding problem, but is intended to impart an awareness of the nature of the problems, their relations along abstract scales of difficulty, and some of the considerations that must guide us in our system design and implementation.

Our first concern, after receiving a copy of the Woods-Kaplan parser and grammar was to get it debugged and running reliably (see preceding report). When that had been accomplished, a simple theme-encoding function was written, enabling the system as a whole to perform (within limits imposed by the status of the dictionary) at a level indicated

by (1) above. During the reporting period, progress has been swift if not always smooth. Performance at levels (2) and (3) has been achieved, and the levels of (4) and (5) will become operational early in the next reporting period. The lexical work associated with the level of (6) is about 35% complete, and the related work on the parser, grammar, and encoding function will follow. A number of sentences illustrating the system's current performance are reproduced below.

Input Sentence:

THE TROOPS FROM SYRIA SUDDENLY INVADED THE JERUSALEM
REGION

Output Sentence:

TROOP /3 SYRIA /3 * SUDDENLY /4 INVADE /4 * REGION /7
ISRAEL /7 *

Input Sentence:

THE TROOPS FROM THE FORTIFIED BORDER OF SYRIA SUDDENLY
INVADED THE JERUSALEM REGION

Output Sentence:

TROOP /3 SYRIA /3 * SUDDENLY /4 INVADE /4 * REGION /7
ISRAEL /7 *

A second approach to automated interactive theme encoding is also being pursued. Called "sequential coding," it is based upon some novel hypotheses concerning the natural logic of textual communications.¹ From the point of view of the implementation, its most striking advantage is the relative simplicity of the program and dictionary structure. An earlier ALGOL version of the sequential coder (PETE) has been implemented, tested, and demonstrated on texts of a political nature. Revisions and recoding of the sequential coding program in FORTRAN IV are now in progress with the aims of: (1) improving its running efficiency, (2) refining its encoding rules, (3) improving and broadening the scope of its interactive facilities, and (4) enlarging its dictionary. The recoding task is more than half completed and will be finished early in the next reporting period.

¹Tripodes, Peter. Note on a Method of Sequential Coding of Content, CCBS, UCLA, May 1971.

Tripodes, Peter. An Automatic Coder Utilizing Sequential Codes, CCBS, UCLA, CCBS-TM-26, December 1971.

Tripodes, Peter. A Refinement of Sequential Coding Methods: Applications to Question Design and Automated Inference, CCBS, UCLA, July 1972.

Accomplishments during this reporting period in the area of interactive data analysis:

- Integration and checkout of all components of the TRACE system.
- Extension of PREP capabilities to handle larger data bases in general and archive data bases in particular.
- Upgrading of PREP to handle general restrictions on recoding and transgeneration functions.

CCBS User Conference

The first CCBS User Conference was held in mid-June. Invitees represented a select cross-section of present and potential users of the CCBS system. Conferees included representatives from various agencies of government, research institutions, and the academic community; fields of specialization of the conferees included international relations, political science, social psychology, engineering, computer science, and architecture and urban planning with such diverse interests as training, operations analysis, planning, forecasting, data management, survey research, and conflict theory. The intent of the conference was twofold: (1) To inform the conferees of CCBS capabilities, and (2) to expose the CCBS system to a wide variety of user needs.

Reflecting this twofold intent, the conference was organized into lecture-demonstration sessions, which were used to describe and discuss CCBS capabilities, and working sessions which were used by conferees to apply CCBS capabilities in the various domains of interest and specialization that were represented.

The conference produced both specific and general levels of evaluation and recommendations for improvement. The specifics, relating largely to use-procedures, have been reviewed and, for the most part, incorporated into the CCBS User Package. The general recommendations related not so much to change--there was widespread endorsement of the CCBS philosophy and implementation--as to directions for future directions both with respect to

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developments and areas of application. These recommendations, especially as they intersect with our own needs, will play a significant part in future planning for the project.

WEIS System

The WEIS (World Event Interaction Survey) System, developed by Charles McClelland, is being adapted to the CCBS User Package. The WEIS data base contains over 47,000 such events, collected from the daily New York Times from January 1966 through May 1972. These events have been coded by: time, initiator, event type, target, and conflict arena. Over 160 nations appear as either initiator or target or both. Events are coded into 63 types, and these are organized into 22 super-categories.

The latest version of the system was originally implemented in an IBM environment; transplanting WEIS into the CCBS/PDP-10 system proved difficult, and the transplanted version proved to be below acceptable levels in terms of operating efficiency because of the large number of data transfers between peripheral storage and core and because efficient data transfers intersect critically with differing hardware architectures between machines.

The task of adapting WEIS to the CCBS/PDP-10 is more than half complete--WEISUM allows the user to count the occurrences of any combination of event categories. It has been fully implemented (with a tenfold increase in efficiency) and WEISCAN, the second major portion of the WEIS system, uses the event categories to search and retrieve the text itself. It is being similarly adapted for incorporation in the CCBS User Package.

Laboratory Facilities

A facility of approximately 6,000 square feet has been developed to provide space for the computer, laboratory, and staff offices on the UCLA campus. In addition to the computer and interaction terminals, the laboratory requires other equipment (for monitoring, recording, stimulus presentation, and information exchange) to support a wide range of behavioral investigation. A closed-circuit T.V., an audio monitoring/recording, and a general control system have been integrated into the laboratory.

Simulation Research and Methodology Development

Laboratory simulation exercises are being conducted at a number of centers for the study of international relations, for evaluation of political-military strategy for crises and long range planning, and for study of other allied topics. One of two divergent approaches is characteristically used in these gaming efforts. In policy-oriented gaming, where credibility and realism are emphasized, data are not systematically recorded and analyzed, methodologies employed are typically unevaluated, and experimental control is deemed unnecessary except for constraining player departures from realism or the gamer's intended focus. In research-oriented gaming, where theoretical and methodological issues are of primary concern, superficial representation of reality and the use of unskilled players have led to extensive criticism and charges of triviality. In either case, because these games are administered, played, and observed manually, they are severely limited in the amount and subtlety of monitoring and control, in the level of detail and volume of data that can be gathered, and in the role played by the analyses of these data. Furthermore, where the complexity of situations being studied does not readily yield to the control sought in the standard application of the laboratory experiment--a situation characteristic of almost all laboratory gaming--these limitations in control or data gathering greatly curtail the value of these exercises for evaluation or research purposes. Consequently, whether policy- or research-oriented, such games are unable to deal with a number of important questions, some of which are so fundamental as to bear on the validity of the games themselves.

Our research plan attempts to join the assets in both approaches and to reduce a number of the limitations associated with each. In particular, an attempt is being made to realize jointly the objectives of the theory-oriented researcher, and the more stringent demands for credibility and relevance of the policy-oriented practitioner, through our newly developed on-line capabilities.

Furthermore, through a strategy that links the data collected in laboratory exercises with that collected in other laboratory and nonlaboratory approaches, we hope to increase the generalizability and utility of simulation studies and data.

Project activities during the past six months are described below:

Scenario Topics, Conceptual Issues, and Scenario Developments

Proposed and developed simulation scenarios will continue to focus on some of the central issues of American foreign policy today--the factors influencing the degree, form and effectiveness of U.S.-U.S.S.R. involvement in local conflict.

A central problem of United States foreign policy in the next decade will be the extent to which the United States can, in future crises, take actions that are commensurate with its conventional and nuclear power, its economic strength, its scientific and technological status, and its interests in the outcome of the crisis. We are concerned with studying the factors which permit or constrain the United States and the Soviet Union from taking action in a set of representative crisis situations.

Conceptual Framework for Simulation Scenarios

While pursuing the detailed development of particular scenarios we have set forth conceptual frameworks that raise questions about the dynamics of great power involvement. Most particularly we have focus on the dynamics of confrontation and commitment processes in these circumstances. The evolving framework and hypotheses of interest are being used to shape scenarios and simulation format in a manner that minimally compromises their policy-validity and their utility for policy analysis. Two areas have been singled out for attention:

Confrontation Theory. Work in this area has explored the field of deterrence theory as it relates to U.S.-involved crises in the

third-world area. This led us to a formulation designed to help us explore the conditions of successful and unsuccessful deterrence. Results of these efforts have been reported in earlier reports and in CCBS-TM-33. In a closely related paper, "Toward Confrontation Theory" (CCBS-P-3), "confrontation" is defined and distinguished from the related phenomena of "crisis," "war," and "deterrence." The objectives of the study of confrontation are outlined, and a case is made for the construction of a framework for a set of propositions as a separate step in the study of confrontation. A quasi-canon of 72 propositions on origins, actions, and outcomes of confrontation is collected. A provisional set of confrontations (1898-1972), candidates for systematic study, is listed.

The Role of Commitment Processes in Defining Foreign Policy.* The current phase of this effort is concerned primarily with testing a set of hypotheses on military commitments in "third area" conflicts below the strategic level: a client state, more or less under the protection of a great power, is faced with a military threat from another state.

The relative importance of a number of relevant contextual factors affecting the operation of "third area" deterrence are explored: the probable consequences of defeat for the client; the strategic nuclear balance between defender and challenger; the regional military balance; the defender's past verbal commitment to defend the client; the defender's ideological value at stake in defending the client; the defender's military, economic, domestic, and future credibility values at stake; the potential negative economic, diplomatic, and domestic consequences if the defender does intervene; the degree of public unity in the client state; the defender's record in meeting past commitment challenges; and, finally, the role of defender, client, and challenger.

*A paper prepared for presentation at the International Studies Association Convention, 14-17 March 1973, New York City, reports on the theoretical framework and research design of this work. A more complete presentation of the method is also described in earlier reports.

This large number of factors and associated consequences cannot be explored systematically in either real world contexts or laboratory simulation. Instead, we have used a systematically designed and modified, individually administered, paper-and-pencil simulation exercise. Each of the relevant contextual factors is described as one of two or more descriptions represented in the form of interchangeable paragraphs of a scenario. In this study, the first four and the last contextual factors have been systematically manipulated and result in sixty-four unique scenario combinations prepared in this fashion. Each of the scenarios incorporating these variables describes a Middle East crisis in 1975. Respondents assumed the perspective of a policy adviser for Israel, Egypt, the U.S., or the U.S.S.R. Questionnaire responses allow us to measure the effects of scenario manipulations and respondent's attitudes on deterrence and commitment responses. In particular, their effects on four interrelated dependent variables are examined: the perception of the defender's credibility, the defender's willingness to increase his credibility by strengthening his commitment, the challenger's willingness to attack the client based on his evaluation of the defender's credibility, and the defender's willingness to intervene if deterrence fails.

The data collection phase of this effort has been completed and the final analyses have been initiated. Ten complete replications of the design consisting of 640 participants were administered to complete the data collection phase. A preliminary analysis based on 512 participants (8 replications) showed that there tended to be considerable consistency among the four national actor roles in their perceptions of the various scenario conditions, in their evaluations of the credibility of the U.S. commitment, in their estimation of the level of U.S. action required to achieve commitment credibility and on U.S. willingness to take that action. At the same time, the considerable differences between Soviet/Egyptian and U.S./Israeli evaluations of the justification of the threatened attack indicated national role differences.

Of the four situational conditions that were systematically varied in the scenario, local military balance had the greatest effect particularly on perceptions, evaluations, and decisions concerning U.S. policy. Given local military superiority, U.S. players indicated considerable willingness to defend Israel--in the event deterrence failed--regardless of the other contextual conditions. However, under conditions of local Soviet/UAR military superiority, U.S. willingness depended on whether the probable Soviet/UAR objectives were extreme or limited or prior U.S. commitments had been weak or strong.

While the local military balance also had an important effect on Egyptian policy, the calculations of both the Egyptian and particularly Soviet players were more sensitive to changes in the strategic nuclear balance rather than the local conventional one. In general, the UAR players were more willing to exploit the crisis and attack Israel than were the Soviets.

Among the many interesting issues raised by these findings, the preliminary analyses tend to indicate that the assumptions underlying the "massive retaliation" doctrine (that strategic superiority is sufficient to deter a whole range of possible provocations) are more consistent with the findings than those of the "flexible response" strategy (that strategic forces are only effective in deterring the more extreme provocations and that sizable local forces are needed to deter more limited commitment challenges)--at least in terms of the challengers' behavior. The defender's actual intentions to support the client, however, seem to depend more on the availability of local forces (such as argued by the flexible response strategists) than on the nuclear balance.

A continuation of the analysis and write-up will be made during the next reporting period.

Methodology for Scenario Design and Construction for International Relations Simulation Exercises

Although simulation games are finding wider usage (in universities and military colleges, as well as in political-military exercises), practically nothing has been written on how to prepare good scenarios, nor have any systematic procedures been developed to assist the scenario designer in organizing information, materials, and concepts. Scenario design remains an art in which only few practitioners achieve products of high quality. As a consequence, most scenarios are designed on a hit-or-miss basis and are excessively costly; the implications for playability, representativeness, and relevance to theory and policy concerns are left to intuitive decision.

A series of papers (to be integrated into a larger work) have been written and others are in progress to provide general and specific guidance on scenario development for study of international crises so as to contribute to an improved quality and economy of gaming. These papers also will include material on how to conduct simulations, on procedures, record keeping, control problems, role playing, debriefing, etc.

In addition to providing instructions to the reader on how to proceed in the construction of a simulation exercise, and examples of exercise materials, we continue to attempt to explicate the step-by-step intellectual process which led us to make certain choices and assumptions, and we will provide the framework for the reader to move through a similar process on his own.

A major development during the preceding period has been the introduction of the metagame approach and its modification for the analysis and design of crisis situations developed by Nigel Howard.* This approach was explored as a tool for the transformation of real world materials into tractable scenario elements and for the

*See Howard, Nigel. Games, Metagames and Rationality. Cambridge, Massachusetts: MIT Press, 1971.

analysis of existing scenarios and expert situational definitions to produce a greater amount of simulator control and understanding of the generated setting. Some modifications are necessary to make this general analytical approach into a useful design technique, and a preliminary report illustrates the specific problems and suggestions (CCBS-TM-34). In this report the metagame analysis technique is explained and basic concepts defined and illustrated by the application of the technique to an existing Mid-East simulation scenario. It describes metagame analysis as a formal technique for the structuring of subjective definitions of situations; the method, itself, in no way prejudices the result of the analysis. The outcome is the result of the author's assumptions concerning the situation. Different assumptions result in different outcomes. The report is intended to show how the metagame analysis technique can be used to structure the crisis focus of a scenario, and suggests certain tentative process hypotheses.

During the preceding period the major emphasis of metagame analysis has been directed toward the acquisition, implementation, and modification of a FORTRAN IV program for computer-aided metagame analysis. A preliminary version of this program is now operational. The computer-aided method allows the analysis of moderately complex real world crisis situations such as might be encountered in scenario simulation.

The current routine takes actors, options, and preference assignments made by the analyst and performs the Boolean calculations necessary to check for a complete analysis. The computer then informs the analyst of any feasible option combinations he might have overlooked in his original assignment and allows these to be assigned. The computer also informs the analyst of contradictory assumptions made during the course of the analysis. The completed analysis may be retained on hard copy or stored for update.

A series of tests has been run to determine the amount of knowledge required to perform the analysis successfully. During the test

period the program capacity has been arbitrarily limited to a total of 25 actors and options. Some knowledge of the metagame analysis method is required to operate the program, but an understanding of the theory of metagames is not a prerequisite. Testing of the computer-aided method resulted in the emergence of a number of suggestions for modification which are currently being implemented or explored. The most significant of these concerns building a metagame analysis of a one-team scenario (since metagame analysis is a kind of simulation) to aid in on-line instruction in the metagame analysis method. Other modifications to the original FORTRAN program obtained from Nigel Howard at the University of Waterloo* include changes in input and output procedures and output displays to make the method more understandable to the user, as well as the option for hard copy.

In another related development, the metagame technique (utilized in the analysis of complex conflict-and-bargaining relationships) was extended by the development of a multiple equilibrium analysis procedure (for locating possible stable outcomes in the conflict-and-bargaining situation) and a "semi-dynamic" procedure for locating likely threats, commitments, moves and bluffs in such a situation. The procedures (and an algorithm for the semi-dynamic procedure) were presented at a meeting of the Western Political Science Association by David Wilkinson (CCBS-P-11, "Metagame Analysis: Equilibrium and Semi-Dynamic Procedures"). Future plans include the specification of the algorithm into an on-line interactive situational-analysis program.

A 1974 Mid-East Scenario for a One-Team Computer-based Simulation Exercise

The general purpose in developing a one-team simulation is to create an international relations game which requires only limited personnel for administration, and affords greater control for research

*"Analysis of Options: An Interactive Computer Programme."
Department of Systems Design, University of Waterloo,
January 1973. (Author not designated)

purposes. It is an effort to provide a simulation format that offers greater efficiency, control, and standardization; this is the rationale for reducing the response roles to a single team, the U.S., while all other nation roles in the game are simulated. Not only can a number of U.S. teams be run simultaneously, but the physical presence of a number of teams adds to the credibility that these other teams are being played "live" rather than being simulated by the experimenter.

A scenario developed for the one-team format explores deterrence and commitment considerations that would motivate an American decision to give large-scale direct military assistance to Israel under conditions of increasing levels of Arab-Soviet endangerment of Israel. The question of substantive policy interest is whether players will accept the consequences of one of the pure strategies (commitment or noninvolvement) or be drawn to compromise alternatives (some level of partial commitment with attendant partial involvement) which are psychologically attractive, but may be strategically poor in a series of escalation moves.

In addition to the methodological and policy focus, questions of a more social psychological nature are also being formulated for this simulation exercise. There is now a sizable and controversial research literature* that claims groups of individuals take more risks than would the same individuals making the decisions privately. Nine dimensions that may influence such shifts in choice have been identified and a few of these will be systematically varied to determine the extent to which they would influence the decisions made in the Middle East scenario. Special attention is being given to variables that would appear to exert an influence on decision recommendations among high-level advisory staff. An empirically based model of the risky shift phenomena

*Pruit, D. G. Choice Shifts in Group Discussion: An Introduction Review, Journal of Personality and Social Psychology, 1971, 20, 339-360. This number of the journal is a special issue devoted to risky shift and contains a number of research reports on this topic.

has been developed as a computer model in which the effects of thirteen experimental variables may be specified and their effect on experimental results studied. Further modification of the all-computer model will be based on examination of these results.

World Dynamics: Analytical Experiments with an All-Computer Model

The Forrester World II model presents the interaction of five variables describing the state of the world social system: population, resources, pollution, capital investment and agricultural investment. The highly aggregated World II model relates these variables in a manner that reflects Forrester's information, his theories, and his world view; as a formal dynamic model, it then "extrapolates" Forrester's assumptions, "deducing forward" from its given assumptions and initial values.

The widespread interest aroused by the World II model is of course a consequence of Forrester's referring its extrapolated behavior back to the real system it seeks to represent. Forrester points out that a computer model, as an embodiment of a theory of system structure, states the theorist's assumptions about the system and thus is only as good as the theory which lies behind it. Therefore, he proposes,

"The reader should examine the assumptions and the relationships for plausibility. If he were to engage in extending and refining the model, he would want to test his alternate hypotheses by altering the assumptions given here to determine which changes in assumptions result in significant changes in system behavior."*

The Forrester World II model invites four types of tinkering: simple analytical experiments (e.g., changing the given initial conditions); reshaping empirical functions; complication of rate equations; and addition of new level variables with their accompanying rate equations and feedback loops. The manipulations described deal with the first two of the four.

*Forrester, J. W. World Dynamics, Cambridge, Massachusetts: Wright-Allen Press, 1971, p. 32.

A basic version of the World II model was received from Dr. Michael R. Leavitt and revised to fit the PDP-10 as "FORCOR.BAS" and WORL2.BAS." A series of analytical experiments with the model showed that, with its "table functions" edited to reflect a different and somewhat more empirically based view of real world relationships, substantial increases in resource availabilities and pollution controls were sufficient to prevent collapse of the model and achieve new stability at a substantially improved "quality of life." Restraints on economic growth (the most controversial segments of the Forrester-Meadows prescription) proved unnecessary in achieving stability within the edited model. Results were presented at a meeting of the International Studies Association/West in a paper by David Wilkinson ("World Dynamics: Analytical Experiments," CCBS-P-12). While no immediate further work on this model is planned for the near future for this small effort, longer term developments have been sketched by Wilkinson ("Political Design and International Studies," CCBS-P-13), which indicate how it might be used in conjunction with other related international relations research that involve decision-making in projected future world environments.

Adaptation of the International Relations Exercise (IRE) to CCBS

Authored and computer programmed by Lieutenant Colonel George L. Draper and based on Guetzkow's INS and Coplin's WPS, IRE was used at ICAF for the first time in 1971. This much improved simulation exercise was subsequently used by the Senior Seminar on Foreign Policy, Department of State, the Army War College, and, to date, by over 1000 Senior Service School and Academy level students.

IRE, like its earlier predecessors, remains a free-form computer simulation but uses an improved scenario, data base, and computer submodels. It is free-form in that the participants are virtually unrestricted in decision options available to them. The impact of political decisions of the participants is reflected in an annual computer-generated report which portrays the "State of the Nation" including a political analysis and the confidence the constituency has in the administration.

The exercise may involve as many as eight nation-players whose attributes are particularized by updated data bases. They are then introduced to a scenario that introduces the participants to a simulated world some date in the future. Each nation is provided with relevant historical information of a privileged and general kind. Each nation is then required during each decision period to define national goals by priority and the manner in which they intend to accomplish these. Available resources, which include political, economic, and military are then allocated and associated actions are taken. The exercise is presently run on a remote timesharing system. ICAF uses teletype terminals to produce annual reports.

CCBS is currently adapting the software so that it will run on the PDP-10 so as to make it available to a larger variety of potential users. It is anticipated that this goal will be achieved about half-way through the next reporting period. With some user experience, a package of improvements will be designed to provide additional computer support for these exercises--both for exercise management and control team monitoring. These modifications should significantly increase the ease of conducting IREs and provide for much needed research evaluation.

A Persian Gulf Scenario

A preliminary version of a scenario was prepared as a candidate scenario for consideration for further study at CCBS. The scenario explores a slowly developing crisis growing out of requirements for protection of super-tankers sailing through the Mediterranean and/or Indian Ocean destined for U.S. East coast ports.

- (1) With attention in the United States and elsewhere centered on the looming world energy crisis, a great deal more attention will be focused on the Persian Gulf.
- (2) Every day 20 million barrels of oil are shipped by tanker through the Persian Gulf and the Straits of Hormuz to Western Europe, Japan, and the United States. This amounts to more than 3/4 of the entire output of oil from the Middle East.

Because of the dependence of Western Europe, Japan, and the United States on this supply of oil, the Persian Gulf takes on a new strategic importance. General Isador Rabin, the former Israeli Ambassador to the United States, described it (particularly the Straits of Hormuz) as "the American jugular vein." If America is to remain a great power, he said, "it will be forced to protect its interests in this area."

- (3) There have been some fears expressed in the United States that because of American military support to Israel in the form of modern weapons, the Arab oil producing states, supported by the Soviet Union, might try to cut off oil shipments from the Middle East to the United States. This danger was emphasized in The Oil Import Question: A Report of the Relationship of Oil Imports to National Security by the Cabinet Task Force on Oil Import Controls, Washington, D.C., 1970, p.31. Such a development could cause the United States great embarrassment and, in the midst of an energy crisis, great hardships.
- (4) This scenario follows the line of thinking laid down by two Soviet political-military experts: E. M. Primakov of the Institute for World Economy and International Relations and V. V. Zhurkin of the Institute of the U.S.A. (as relayed to Thomas W. Wolfe of the RAND Corporation). They described a future possible Middle East confrontation in the following terms:

"There is a renewal of Arab-Israeli hostilities at some future date. Arab countries blame the United States for backing Israel and a wave of reprisals against U.S. oil and other interests in the Middle East takes place. The United States, sensitized by the energy crisis, sees not only its economic but its vital strategic interests jeopardized by the loss of access to Middle East oil. It therefore intervenes with military forces. The Soviet Union cannot stand idly by when its clients plead for help. It therefore takes unspecified countering action and the stage is set for a dangerous confrontation."

The words "unspecified countering action" in the above quotation permits one to suggest one possible effective course of action open to the Soviet Union which would be difficult if not impossible for the United States to prevent or rectify.

- (5) The scenario would involve a mining operation in the Straits of Hormuz by Soviet and Iraqi naval and air forces. Recent developments in sea mines have enormously increased their versatility and effectiveness. American mining operations off the North Vietnam coast in May 1972 demonstrated that effective minefields can be laid over an extensive area by air in a single night. Mines are no longer merely anchored in one place but can move toward a ship target in response to an acoustic or pressure stimulus. Mines can be laid in much deeper water than in former years. Preset arming and deactivating devices permit the country laying the mines to know just when they will become operative or deactivated.
- (6) What makes the scenario a novel and sophisticated one is that sea mines are passive weapons. You have to run into them or into the area of their effective operation in order to be hurt. One could expect that in the case involved in the attached scenario the Iraqi and Soviet Governments would warn international shipping to avoid the mined area. Neutral and world shipping accepted the American minefields off the Vietnam coast in 1972 without serious protest. One may assume that a mine barrier in the Straits of Hormuz would produce a slowly developing low-level international crisis rather than an explosive one.
- (7) The scenario assumes that there is a renewal of fighting between Egypt, Libya, Syria, Iraq on one side and Israel on the other. In this fighting Arab forces are defeated and in their exasperation blame the United States for their losses. The radical Arab states Syria, Libya, and Iraq try unsuccessfully to get an Arab and Iranian embargo against the shipment of Middle East oil to the United States. Saudi Arabia, Kuwait, and Iran continue to make oil shipments to the United States, Japan, and Western Europe. The scenario further assumes that the radical government of Iraq persuades the Soviet Union to participate with it in a mining operation designed to close the Straits of Hormuz (see attached map) to oil shipments.

- (8) If this were done, it would produce not only a slowly developing crisis (as the United States, Japan, and the European Economic Community ration their oil) but a fairly prolonged one, making possible a game with several move cycles assured. It would be a fairly prolonged crisis because modern mines are difficult to sweep up. They have various kinds of detonators that respond to different stimulation: contact, magnetic, acoustic, pressure. The Soviet Indian Ocean squadron possesses the only minesweeper in that part of the world. A minefield laid in the Straits of Hormuz would interrupt oil shipments for several months. If oil was in short supply in the West, this might produce a low-level crisis lasting over several months that becomes increasingly difficult with the exhaustion of fuel reserves, and permit a slowly developing crisis game involving teams representing not only the radical Arab states and the Soviet Union, but also the United States, Japan, and the European Economic Community.

The entire scenario, presented in CCBS-TM-46, illustrates how such a development might occur.

Experimental and Para-laboratory Studies of Interparty Conflict

The simulation approach, because of its complexity, needs to be closely interrelated at many levels with other techniques of investigation to clarify its findings, to serve as a direct source of hypotheses, and as a simple setting for developing and testing new methods. It is necessary, then, that the research program continue to range widely in its approaches to problems from paper-and-pencil situations to computer-based experimentation and that data from these studies be more closely linked. While these studies are only a small part of the total effort, we believe it is particularly important to continue two lines of investigation in support of the simulation activities: (1) our earlier program of experimental studies in the new computer laboratory, and (2) SCENQUEST studies.

While no new experimental studies are being undertaken until the next reporting period when the laboratory is available, results of earlier studies continue to be analyzed and reported. The results

of a study on attempts to shape cooperative behavior in a prisoner's dilemma game has been written up for submission for presentation at the next American Psychological Association Meeting.

SCENQUEST--A Scenario Questionnaire Technique for Studying Behavior in Complex Social/Political Setting

Many in-process phenomena cannot be studied easily in simulation exercises because they occur rarely, or follow unique patterns of antecedent events, or require more extensive subjective analysis than can be easily obtained during the exercise.

Furthermore there is a need for systematic evaluation of large numbers of variables under conditions which allow their assessment to be made economically, in terms of both time and money, that the present SCENQUEST (a scenario-questionnaire) procedure was evolved.

Briefly, in the SCENQUEST approach, the respondent is given a written scenario of an ongoing situation. This synopsis may be presented in dramatic, real-life terms or in bare-bone, analytical ones, and may concern situations as complex as those presented in real world crises or as simple as those in a prisoner's dilemma experiment. The synopsis provides a summary history of the events and decisions made by all relevant actors up to a given point. The respondent reads the scenario from the point of view of one party in the situation; he is then asked to respond as if he were in the situation with the history as it is given and in the designated party's place. He then records his responses to a questionnaire that is designed to assess the respondent's interpretation and response to the situation presented.

The Effects of Variation in Size and Reducibility of Objective Conflict on Pre-Bargaining Perceptions. Mutual incompatibility of one party's goals with another's is at the very heart of most definitions of social conflict,¹ yet the outcomes of conflicts are

¹Fink, D. F. Some conceptual difficulties in the theory of social conflict. Journal of Conflict Resolution, 1968, XII, 412-460.

usually not rigidly set or completely determined by objective constraints. These are frequently open to redefinition. This view of conflict as open in scope found enthusiastic support from social psychologists whose focus is on individuals and small groups in settings where attitudinal and emotional issues are primary and where real, inherent conflicts are secondary. More than a decade of psychological studies on social conflict, in both the laboratory and the field, demonstrate that conflict may occur where there is no actual incompatibility of goals and that it may be exaggerated through motivated misperception and misunderstanding,² through limited cognitive comprehension or faulty or incomplete information.³

If conflict expansion could be traced to psychological determinants, psychologists optimistically argued that through the elimination, reduction, or control of these factors, more successful conflict reduction could be achieved at all levels of intra- and extra-societal conflict. This optimism was generally not shared by scholars of international conflict. They criticized psychologists for failing to recognize the discipline-limited nature of findings derived from experimental conflict settings that have rarely exhibited the high levels of mutual incompatibility and important asymmetries of real world conflict.

In a study currently being written up for publication, we explore the effects of low versus high levels of objective conflict, defined by the amount of incompatibility in the division of an outcome under conditions where bargaining over the division of a fixed amount is to be completed in a single session or divided over ten separate occasions. As in an earlier paper on the effects of size and form of bargaining incentives by Lanto and Shure,⁴ we

²White, R. K. Nobody Wanted War. New York: Doubleday, 1970; Deutsch, M. The Resolution of Conflict. New Haven: Yale University Press, 1973.

³Hammond, K. R. New directions in research on conflict resolution. Journal of Social Issues, 1965, 21, 44-66.

⁴Lanto, S. and Shure, G. H. Effects of size of payoff and real versus imaginary rewards on prebargaining perceptions. Proceedings, 80th Annual Convention, APA, 1972, 231, 232.

assume that the size of incompatibility of interests and the fractionation of conflict issues over time will have important effects on conflict resolution behavior. As in other studies,⁵ we anticipate these will be mediated via the S's subjective definition of conflict size, perceived importance of issues, anticipated difficulties of resolution, aspirations and strategies, and feelings engendered by his view of the other party's anticipated behavior and intentions. As in the Lanto and Shure paper, this study focusses exclusively on the preexperimental or orientation phase of bargaining and assesses a relatively large set of potentially relevant facets of the S's perception that may be affected by the variables manipulated.

A second application of the SCENQUEST method, a study on commitment processes, is described on pages 25-27 of this report.

⁵Kelley, H. H., Shure, G. H., Deutsch, M., Faucheux, C., Lanzetta, J. T., Moscovici, S., Nuttin, J. M., Jr., Rabie, J. M., and Thibaut, J. W. A comparative experimental study of negotiation behavior. Journal of Personality and Social Psychology, 1970, 16, 411-438; Shure, G. H. and Meeker, R. J. Bargaining processes in experimental territorial conflict situation. Peace Research Society, Papers, XI, 109-122; Shure, G. H., Meeker, R. J., Moore, W. H., Jr., and Kelley, H. H. Computer studies of bargaining behavior: The role of threat in bargaining. (Rep. No. SP-2916) Santa Monica, California: System Development Corporation, 1966.

Future Plans

This project is being continued under a new contract (AF30602-74-C-0016). In the main, the future plans for the current project are incorporated into, and described in detail in, the work proposed under the new contract, but there are three notable exceptions: work on the virtual memory hardware and software will be completed during the next quarter; some hardware and equipment components, required to complete the system, will be acquired; and final documentation will be completed--these will be reflected and/or incorporated into the final report of this project.

Professional Conferences, Presentations and Activities:

Gerald H. Shure

Attended Arms Control and Foreign Policy Seminar, Pasadena, California, January 9.

Meeting with Dr. Donald Bitzer at Conference on Impact of Communications on Society, California Institute of Technology, February 6.

Meeting with Dr. Dana Main, University of Michigan, Ann Arbor, February 17-18.

Meeting with Dr. Andrew Molnar, National Science Foundation, Washington, D. C., February 19-22.

Delivered address and chaired paper at ISA Conference, New York City, March 15-17.

Participated in ARPA Conference on Research Needs for Defense Decision Processes, San Diego, June 25-July 7.

Visitors to CCBS. January - June 1973

Dr. Helen Orlander, Center for Training in Community Psychiatry, Los Angeles, January 5.

Dr. John Bayless and Robert Chapman, January 17.

Dr. Judea Pearl, Department of System Engineering, UCLA, February 2.

Professors Kumon and Kayay, University of Tokyo, Japan, February 7.

Sam DiCarlo, RADC; Jim Altman, Synectics; Robert DeHaven, Synectics; Stan Hovey, Synectics; George Lawrence, ARPA, February 12-14.

Drs. Emir Shuford, Tom Brown, William Sibly, RAND Corporation, February 16.

Dr. Joseph Ben-Dak, Jerusalem, Israel, February 27.

Dr. Paul Hammond, Dr. Bill Jones, Dr. Charles Powell, Dr. Harvey DeWeerd, Michael Banks, London School of Economics, March 1.

Lt. Andrews, RADC, March 2.

Emir Shuford, RAND Corporation; Dr. Robert Brennan, Dr. David McMullan of Department of Education, Mrs. Betty Wenerser, Instructional Resources Center, SUNY, Stony Brook, New York

Mr. Joseph Markowitz, Cambridge Project, March 5.

Mr. Ernie Wilner, March 6.

Dr. Olaf Helmer, March 8.

Dr. Craig Fields, Harvard University, March 8.

Milton Worthy, Operating Systems Inc., March 14.

Professor James Rosenau, Ohio State University, Columbus, Ohio, March 16.

Dr. Davis Bobrow, University of Minnesota, March 21.

Col. George Draper, April 4

Dr. Carlo Schaerf, International School on Disarmament and Research on Conflict, Rome, Italy, April 5.

Dr. Vaughn Blankenship, Prog. Mgr., Social Systems and Human Resources, NSF/RANN, Washington, D. C., April 12

Mr. Robert DeHaven, Synectics, April 26.

Professor Takeshi Utsumi and associates, Tokyo, Japan, May 9.
Dr. Ed Meyers, Dartmouth, Hanover, New Hampshire, May 10.
Dr. George Lawrence, ARPA, May 10-11.
Drs. Saxon, Trueblood and Barber, UCLA; Dr. Dana Main, University of Michigan, May 14.
Jim Altman, Synectics, May 17.
George Lawrence, June 5.
Dr. Joseph Young, ONR, Washington, D. C., June 6.
Professor Charles McClintock, UC Santa Barbara, June 7.
Dr. Ian Shepanik, University of Waterloo, Canada, June 8-11.
Dr. Nigel Howard, University of Waterloo, Canada, June 10-12.
Dr. George Lawrence, June 11.
ARPA/CCBS User Conference, June 11-13.
Mr. Bernard DiTano and Mr. Garry Barringer, RADC, June 18.
Mrs. Alita Sanders, June 19.
Mr. Jess Gates, Synectics, June 19.
Mr. M. Muchisuddin, American University, Washington, D. C. and Dr. Edward Azar, University of North Carolina, June 21.
Professor Lawrence Stolurow, SUNY, Stony Brook, New York, June 21.
Dr. Emir Shuford, RAND Corporation, June 21.
Lt. Col. Joel Synder, SAGA, June 25.

Project Documentation. January - June 1973

- CCBS-TM-41 A Virtual Memory System for the PDP-10 KA10 Processor, Cooperband, A. S. and Hopkins, D., April 1973.
- CCBS-TM-42 A Delphi Study of Factors Affecting Quality of Life, Dalkey, N. C., February 1973.
- CCBS-TM-43 SENTRY: CCBS System Watchdog, Functional Description, Fisher, W., April 1973.
- CCBS-TM-46 A Persian Gulf Scenario: A Preliminary Version, DeWeerd, H., June 1973.
- CCBS-TM-47 The Effectiveness of Pacifist Strategies in Bargaining Games, Shure, G. H., Meeker, R. J., and Hansford, E. Reprinted in Interpersonal Behavior in Small Groups, Ofshe, R. J. (ed.), Englewood Cliffs, New Jersey, 1973.
- CCBS-P-6 A Paper-and-Pencil Simulation Study of Political-Military Commitment Processes, Rasch, R. L., and Shure, G. H., 16 March 1973.
- CCBS-P-7 A Content Analysis of a Policy-Focused Laboratory Simulation: A Middle East Nuclear Crisis, Shure, G. H., Greenstein, S., DeWeerd, H., and Meeker, R. J., 16 March 1973.
- CCBS-P-11 Metagame Analysis: Equilibrium and Semi-Dynamic Procedures, Wilkinson, D., April 1973.
- CCBS-P-12 World Dynamics: Analytical Experiments, Wilkinson, D., March 1973.
- CCBS-P-13 Political Design and International Studies, Wilkinson, D., March 1973.